

REMARKS

Claims 1-40 remain in the application. Claims 1 and 21 are amended to emphasize distinctions over cited art.

Claims 1-2, 15, and 20 are rejected under 35 USC 102(b) as being anticipated by Reed (U.S. Patent 5,589,692).

Reed discloses sub-nanoscale electronic systems and devices, wherein micro-electronic semiconductor integrated circuit devices are integrated on a common substrate with molecular electronic devices.

Applicants' independent Claim 1, as amended, is directed to an electric field activated molecular switch comprising a molecular system that has an electric field induced non-redox type of band gap change resulting from an intramolecular change in conjugation as p, π -electrons of the molecular system, through its highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO), are alternately localized and delocalized over the entire molecular system by an applied electric field. The non-redox type of band gap change results from an intramolecular conformational change in conjugation, and does not involve an oxidation-reduction reaction.

Dependent Claims 2, 15, and 20 depend from Claim 1.

The Examiner argues that Reed discloses a molecular switching device, which has a band gap that is induced by an electric field, in which there is a change between molecular orbital conformations. The Examiner cites Col. 3, lines 22-25, Col. 20, lines 3-10, and Col. 6, lines 7-13 in support of his argument.

The Col. 3 citation is considered to be inapposite. The cited passage states:

"Theoretically, further downscaling of devices would still be achievable with the appropriate device technology, IF the approach could simultaneously address the interconnection, reliability, and implied fabrication limitations."

The immediately preceding paragraph is directed to conventional semiconductor integrated circuit technology, so the quoted paragraph is directed to the downscaling of devices based on that technology. Such a statement by the

patentee hardly discloses **molecular** switching devices, but only smaller single crystal silicon devices.

With regard to the citation at Col. 20, this is a discussion of a molecule having photovoltaic properties, namely, bacteriorhodopsin, which exhibits photoisomerization between two stable molecular orbital configurations. Specifically, as stated by the patentee, incident light in a dye molecule produces a singlet excited state, which transfers an electron to a remote bacteriorhodopsin molecule, where the absorption level due to the molecular orbital reconfiguration changes by ~0.35 eV.

There is no disclosure in the Col. 20 reference of "an electric field induced band gap change resulting from a change in conjugation as p, π -electrons of the molecular system, through its highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO), are alternately localized and delocalized over the entire molecular system by an applied electric field", as claimed by Applicants. The statement that light incident on a dye molecule produces a singlet excited state and transfers an electron to a remote bacteriorhodopsin molecule says nothing about any change in conjugation via localization/delocalization of the molecular system.

Further, all of the mechanisms disclosed and claimed by Applicants are **intramolecular** in nature (electric field induced rotation of a rotor of a molecule, electric field induced charge separation or recombination of a molecule via chemical bonding change, and electric field induced band gap change via molecular folding or stretching). In direct contrast, the bacteriorhodopsin-based scheme of Reed is **intermolecular** in nature. As clearly stated in the cited portion (Col. 20, lines 3-10), "incident light in a dye molecule produces a singlet state, which transfers an electron to a **remote** bacteriorhodopsin molecule". Such a transfer of electrons takes place from one molecule to another molecule. No transfer within a single molecule is disclosed or suggested; this is in contrast to Applicants' molecules, in which each molecule in an electric field experiences the intramolecular effects for which it is intended.

Finally, transfer of an electron from one molecule to another is simply an oxidation-reduction (redox) reaction. Applicants very clearly state in paragraph 0071: "[t]hus, the molecule is never oxidized nor reduced in the toggling of the switch, in contrast to prior art approaches". Applicants have amended Claim 1 to emphasize

this distinction of their invention over that of Reed, as well as specifying that the change in conjugation is an intramolecular change.

The reference to Col. 6, lines 7-13, is directed to π -orbitals and "extended states", where "conjugated" conductive polymers are those which have overlapping π -orbitals. The resulting extended molecular orbitals provide a pathway through which electrons can travel, "IF an external field is applied and IF excess electrons are present, to provide conduction".

Conjugated conductive polymers are well known. However, as above, there is no disclosure here of a change in the band gap through a non-redox means, resulting from a change in conjugation as p, π -electrons of the molecular system, through its highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO), are alternately localized and delocalized over the entire molecular system by an applied electric field.

The Examiner then argues that with respect to the limitation of alternately localized and delocalized that "this is simply a recitation of the theoretical mechanism of delocalization, and would therefore be encompassed by the disclosure made by Reed of delocalization", citing Col. 20, lines 3-10.

There is absolutely no disclosure of delocalization at Col. 20, lines 3-10. This is simply a disclosure of movement of electrons under the influence of an electric field. In particular, as shown above, the movement of electrons is from one molecule "to a remote ... molecule". Again, such a movement of electrons is *intermolecular*, rather than *intramolecular*.

The Examiner points to Col. 13, lines 22-28, as suggesting the fact that there is an energy barrier between different conformations implies that there are energy minima and maxima.

To whatever extent that may be, there is not the slightest disclosure or suggestion of a change in the band gap, resulting from a change in conjugation as p, π -electrons of the molecular system, through its highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO), are alternately localized and delocalized over the entire molecular system by an applied electric field.

The Examiner notes that Reed's molecules can be between electrodes, citing Fig. 9.

Applicants do not dispute this. There are many different types of molecular-based devices, all functioning on different mechanisms, all disposed between electrodes. Applicants' claims are directed to a specific set of molecules, employing mechanisms for switching not heretofore known in the art.

The Examiner notes that Reed's molecules can be used in information storage, which includes memories, citing Col. 28, lines 48-55 and lines 64-67.

Again, Applicants do not dispute this, for the reasons given above with respect to the use of electrodes.

The Examiner points to Reed's Figure 7A that the molecules have groups that can rotate around bonds.

First, it is believed that the Examiner meant to refer to Figure 6, not Figure 7A, since Figure 6 illustrates a molecule, and Figure 7A does not.

Second, the Examiner is respectfully requested to point out just where the rotors are. None of the thiophenes have a collinear rotational axis allowing rotation, and the benzene ring has no dipole allowing field coupling for rotation. There is nothing stated, implied, or even overlooked by Reed that has any potential of a rotor-stator mechanism. The Examiner's attention is respectfully directed to Model (1) beginning on page 15 of the specification, which describes in detail the requirements of a rotor-stator system.

Finally, the Examiner states that it is expected that the bonds have stretching modes as well, as this is a property of bonds when the thermal energy is available at room temperature and higher temperatures.

It is true that elevated temperatures may cause bonds to stretch. However, as described in Model (3), beginning on page 31, it is the influence of the electric field causing sufficient stretching in a molecule to break the conjugation of the molecule. This is not a thermal effect, as described by the Examiner, but rather is an effect of the electric field.

All claims are based on the change in the HOMO-LUMO band gap as a result of an applied electric field. However, Reed fails disclose such a change in the HOMO-LUMO band gap as a result of an applied electric field. Thus, this reference cannot fairly be considered to anticipate or even remotely render Applicants' claims obvious.

Reconsideration of the rejection of Claims 1-2, 15, and 20 under 35 USC 102(b) as being anticipated by Reed is respectfully requested.

Claims 3, 6-8, 11, 12, 16, 18, 19, 21-23, 26-28, 31-32, 35, 36, and 38-40 are rejected under 35 USC 103(a) as being unpatentable over Reed et al in view of Heath et al (U.S. Patent 6,198,655).

The Reed et al reference is discussed above. Heath et al disclose electrically addressable volatile and non-volatile molecular-based switching devices. The molecular devices include certain [2] catenanes as bistable molecular complexes which are sandwiched between two switch terminals. The switches are said to be extremely small and have dimensions which range from several microns down to a few nanometers. This reference is quite similar to U.S. Patent 6,459,095, cited in paragraph 0002 of the present specification in its disclosure of catenanes.

The Examiner admits that Reed is silent with respect to the recited limitations of the claims with respect to the first and second states and the relationship to the rotor portion and with respect to the junction as recited in the claims. However, the Examiner argues that

“... it would have been obvious to one of ordinary skill in the art at the time of the invention from Fig. 3 and relating Fig. 3 to Fig. 4a and Fig. 4b that there are rotor portions of the molecule as shown in Fig. 3 and labeled 3 in the figure and that Fig. 4a and 4b show the minima and the maxima in the energy of the molecule with the conformation changes. In addition, the molecule has extended conjugation as shown in Fig. 3, and that this can also be a mechanism of raising the molecule to an excited state (col. 3, lines 25-28), as is well known in the art that there can be pi-bond breaking and forming as part of the conformation changes.”

Applicants have discussed Heath et al extensively in their previous Amendment. Essentially, Applicants showed that Heath et al disclose and claim reduction-oxidation (redox) reactions to effect switching, whereas Applicants' invention is directed to an E-field induced molecular conformation change via a **non**-redox process (see paragraph 0071 of the present specification). As noted above, Applicants very clearly state in paragraph 0071: “[t]hus, the molecule is never oxidized nor reduced in the toggling of the switch, in contrast to prior art

approaches". Indeed, the present invention was made with the intention of employing a different, non-redox mechanism for switching, being well aware of the Heath et al invention. Claim 21 is amended to emphasize this distinction over Heath et al.

Further, it is noted that the molecule of Heath et al is an interlocking molecular complex, whereby two molecules are interlocked. There is no covalent bonding between the two moieties. Applicants' molecules single molecules are fully covalently bonded.

At best, the Examiner is combining two references, both directed to redox mechanisms, to reject Applicants' claims, which are directed to non-redox mechanisms.

Further, neither Reed nor Heath et al teach rotor-stator technology, so the Examiner's claims about the combined teachings of Reed and Heath et al relative to rotor-stator are considered to be inapposite. Heath et al teach a switching composition consisting of a pair of interlocking molecules (a molecular complex) that translate with respect to one another and in so doing undergo a redox reaction. Applicants' technology involves no redox chemistry, as shown above. While it is possible that the ring of Fig. 3 may rotate around the second inter-locked molecule, such rotation serves no function, nor would such rotation involve a rotor-stator type connection.

Reconsideration of the rejection of Claims 3, 6-8, 11, 12, 16, 18, 19, 21-23, 26-28, 31-32, 35, 36, and 38-40 under 35 USC 103(a) as being unpatentable over Reed in view of Heath et al is respectfully requested.

Applicants appreciate that Claims 4, 5, 9, 10, 13, 14, 17, 24, 25, 29, 30, 33, 34, and 37 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. However, based on the foregoing arguments, Applicants assert that the remaining claims are also allowable.

The foregoing amendments and arguments are submitted to place the application in condition for allowance. The Examiner is respectfully requested to take such action. If the Examiner has any questions, the Examiner is invited to contact the undersigned at the below-listed telephone number. HOWEVER, ALL WRITTEN COMMUNICATIONS SHOULD CONTINUE TO BE DIRECTED TO: IP ADMINISTRATION,

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Respectfully submitted,

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